



LOGISTICS

Park at the Tree Molds Parking Lot. To guide your students around the Broken Top Loop, including Buffalo Caves, will require a minimum of 2 hours and cover a distance of 1.8 miles. Because none of the loop trail is surfaced, with the exception of the segment along the road, and there are areas where the trail is very steep, the trail is not recommended for students with walking disabilities. Make students aware that they will be gone for over 2 hours and that, other than the vault toilets at the parking lot, there will be no restroom facilities along the route. For safety reasons, as well as for students to see and for the teacher to be heard, it is recommended that groups be kept to 30 students or less.





SAFETY

1 Each person should carry at least a pint of drinking water. **2** A first-aid kit should be carried in the event that a student trips or falls and gets a cut or scrape. **3** Students should wear long pants, which can prevent or reduce the severity of a cut or scrape. **4** Students should wear sturdy shoes, which increase traction and lessen the chance of slipping or turning an ankle; sandals should not be permitted. **5** If you are going into the Buffalo Caves with your group, each person should have a reliable flashlight.

Safety messages throughout the Teachers' Guide are highlighted in **RED**.

THINGS TO BRING ALONG

▶ EACH LEADER

*water
first aid kit
map and guide*

▶ EACH STUDENT

*water
long pants
sturdy shoes*

▶ OPTIONS

*hand lens
binoculars
camera*

RESOURCE PROTECTION

Please help us to protect this resource so that future generations of students can also enjoy it. Insist that students stay on the trail, do not litter or throw rocks, and take only pictures. You can point out that, with about 225,000 visitors per year, it wouldn't take long for the place to look very different if people were allowed to collect things or take home souvenirs from the Monument.

Resource protection messages throughout the Teachers' Guide are highlighted in **BLUE**.



► *If each visitor took just one hand specimen, 86 small dump truck loads of material (4 cubic yards each) would be leaving the park each year.*



HARD AS A ROCK?

While the lava flows seem indestructible, these rocks are very fragile! The crust covering the lava flows is brittle and will fracture and break if you step on it. Any place where the lava is orange instead of black indicates that the crust has been damaged and the oxidized lava underneath is now exposed. Hollow ropy lava, crumbly crater walls, and honeycombed cinders can be destroyed by a careless step. You can make a difference.

Stay on the trails wherever possible.

If exploring the Monument where there are no trails, please follow these low-impact hiking techniques:

- The first choice is to walk on soil-covered areas, then cinders, then the lava flows.
- Do not climb or walk on fragile features such as the monoliths, spatter cones, or tree molds.

We appreciate your cooperation! Remember,
THE ROCKS ARE FRAGILE!

PARKING LOT

Repetition is the mother of learning. Begin by reviewing the geologic setting of Craters of the Moon. Have students summarize what they have learned at the visitor center or previously in school about the Yellowstone Hot Spot (original *source* of heat and molten basaltic material), The Great Rift (*pathway* related to Basin and Range Type Faulting), and the Stages of Eruption.

Because a number of cinder cones are visible from here, it is an excellent place to discuss what happens when **magma*** comes to the surface with a lot of dissolved gasses.

*** If a scientific term is defined in the glossary, it will appear in bold print the first time it is used.**



Big Cinder Butte, one of the largest basaltic cinder cones in the world.

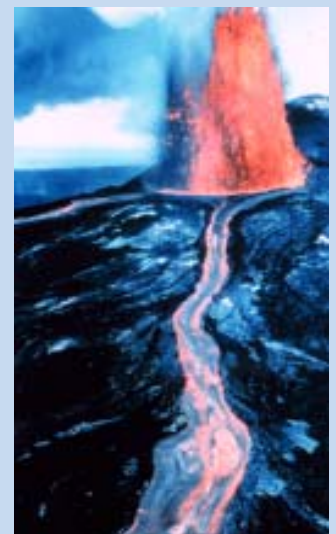
▶ The Great Rift will be discussed in more detail at Stop 1, Eruptive Fissure, so plan on discussing the Great Rift at that stop. Do the film can eruption again, or ask students to think back to when they saw the demonstration earlier.



FILM CAN EXPERIMENT AND ANALOGIES TO VOLCANIC ERUPTIONS

This simple experiment gives students a tangible model to which to relate volcanic activity:

Fill a plastic film can about 1/3 full with water and then drop in an “Alka-Seltzer” tablet; cap it and make sure it isn’t pointing at anyone (the cap may shoot as high as 20 feet in the air). Just like the film can lid, if molten rock comes to the surface with a lot of dissolved gasses it too gets thrown high into the air when the pressure is released. (You can also use a pop or champagne bottle analogy.) As the material rains back down, it can pile up to form cinder cones. Dump what remains of the tablet on the pavement. This represents a later stage when lava pours out more quietly onto the surface. Just like the tablet, which is still fizzing, magma that has had much of the pressure released is free to flow out onto the surface in a more quiet fashion in the form of lava flows. This flowing lava still has gasses left in it, which produces the holes that the students will see in the lava as they walk from the parking lot to where the trail starts up the side of Broken Top (NE of the parking lot).



Big Cinder Butte, SE of the parking lot, is a great example of magma coming to the surface with a lot of dissolved gasses! It is the largest **cinder cone** in the park, and one of the largest basaltic cinder cones in the world. The fountain of fire that produced it was probably greater than 1,000 feet high, and possibly more than 1,500 feet. The cone itself is more than 700 feet high (therefore, the minimum height for the fire fountain had to have been 700 feet). Big Cinder is more than a mile across at the base.

Big Cinder is asymmetrical (lopsided) in shape, which was caused by more material being carried and deposited in the downwind direction by the prevailing winds. (The low hills on the right as you view the cone from the parking lot are also a part of Big Cinder Butte.) Many cones at Craters of the Moon are higher on their NE sides because the prevailing winds in the past, just like today, were out of the SW.

Big Cinder formed about 6,000 years ago and the hill (unnamed cinder cone) rising behind the parking lot is also believed to be of similar age.

In comparison to composite or strato volcanoes, such as those found in the Cascade Range, with which most students are often more familiar, the cinder cones may seem small, but for their type they're really not. Sometimes going over the dimensions of Big Cinder, in addition to telling the students that it is a world-class feature, will leave the students with a more accurate impression.

You can ask students to speculate on why Big Cinder is lopsided. Some may be able to guess that the wind did it. This concept can be reinforced at either Stop 2a or 2b when viewing Silent Cone and Big Craters from along the trail. You can also point out to your students that they are drawing conclusions based on concrete evidence to explain what must have gone on in the past—uniformitarianism or the concept that the present is the key to the past.



STUDY OPTION: PLANTS & SOILS

Look at some of the plants here, while students are taking turns using the restrooms. Have the students examine scorpionweed and dwarf buckwheat with hand lenses and describe what they see. Descriptions, pictures and information on how the plants are adapted to survive in this not only harsh volcanic terrain but also high desert environment can be found in Appendix III. Good plants to study at the parking lot are scorpionweed, dwarf buckwheat, sulfur buckwheat, antelope bitterbrush, rubber rabbitbrush, and sagebrush. Cut bank along sidewalk is also a great place to talk about loess - see page 11 for a description of loess.

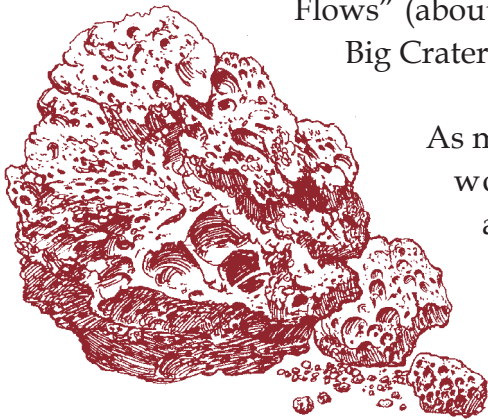
"Wildflowers of Craters of the Moon National Monument," available in the Natural History Association bookstore, is a useful guide on this subject. Appendix IV is a list of commonly seen plants.



Dward buckwheat.

Follow the paved trail on the south side of the road to where it forms a T intersection with the loop. Turn left.

Point out as students walk by the flows that the lava is filled with gas holes and resembles Swiss cheese. The lava flow that the road passes over is part of the “Blue Dragon Flows” (about 2.1 Ka) that originated in the Big Craters/Spatter Cones Area.



*Lava is often filled with gas holes.
It reminds many people of Swiss cheese.*

As mentioned during the teachers’ workshop, the **aa** or rough-appearing material seen along the road is actually slabby pahoehoe (chewed up lava in which the ropey **pahoehoe** nature can still be seen on the tumbled plates and slabs). Slabby pahoehoe is the result of shearing

caused by the steepness of the slope it was flowing down or the roughness of the bed surface or possibly both. You can point out where the lava switches back to pahoehoe probably because the slope decreased as the flows came upon the edge of the spatter rampart, the low hill next to the eruptive fissure. It could not switch back to pahoehoe if it was caused by cooling and degassing.



Ma = million years ago
Ka = thousand years ago

▶ **Mother Nature’s taffy rapids.**

▶ *This discussion is probably too complicated for young students, but may be appropriate for earth science students.*

▶ **PROCEED ...**

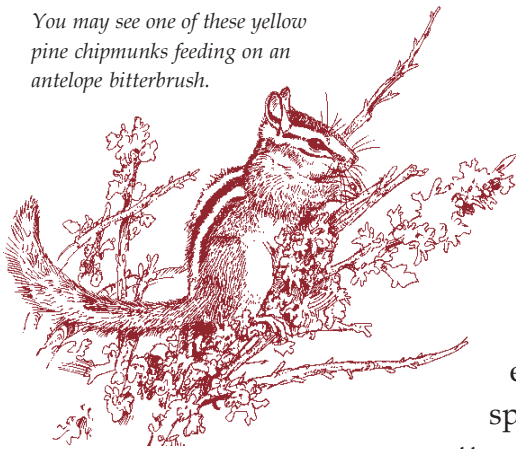
690 feet to where the trail joins the loop.

ERUPTIVE FISSURE

The Great Rift, the pathway that allowed molten rock to come to the surface runs from north of the visitor center, through this area, and to the SE, a minimum of 52 miles. As portions of the rift were forced open by rising magma, huge amounts of molten rock were spewed out onto the surface of Craters of the Moon.

The steep-walled pit at the start of the trail is one of the eruptive fissures that built the cinder cone we call Broken Top.

You may see one of these yellow pine chipmunks feeding on an antelope bitterbrush.



Because the Blue Dragon Flow wraps around and partially fills in the fissure, the eruptive fissure and the cone that was built from it, i.e. Broken Top, have to be slightly older (>2.1 Ka).

The material that looks like it was flowing down into the fissure on either side is **spatter**, and forms a spatter rampart on the right. This spatter was thick liquid rock that was thrown out. After it landed and while it was still plastic, it crept or flowed back toward the fissure under the tug of gravity.

Point out that both the side of the volcano on the left and the low spatter rampart hill on the right are mantled or covered with numerous volcanic bombs as well as spatter. The main difference between spatter and bombs is that bombs were ejected higher and had more air time.



The depression in this picture is an eruptive fissure. The material that built Broken Top was ejected from this fissure.



► PROCEED ...

435 feet, about halfway up the slope on the right-hand side. The small limber pine tree here makes a good place to stop for people to catch their breath, to introduce the limber pine, and to make other observations.

LIMBER PINE

Have the students look across at the lava flows on the other side of the road. Ask which seems easier for life to get a foot hold on, the rough or the smooth lava. Both are the same age. It should be obvious to most students that there is more vegetation on the smooth or pahoehoe lava. Most rocks at Craters of the Moon are too young to have broken down and produced much soil. Plant life is dependent on the deposition of wind-blown soil in order to have a growth medium in which to live. In general the older the lava flow or cinder cone, the more wind-blown soil that has been deposited and, therefore, the more plant life that exists.

The pahoehoe has more plant life because the soil that has accumulated is close enough to the surface that if a seed germinates it also has sunlight to conduct photosynthesis.

The slabby pahoehoe or rough lava has less life because the cracks are so deep that when a seed germinates there often isn't any light available. In Hawaii, just the opposite pattern is true. In Hawaii because of the hot moist climate and the greater surface area of the very rough clinkery lavas, known as aa, they break down much more rapidly than pahoehoe. Also, because of our high desert environment we have about the same amount of vegetation after 2,000 years as Hawaiian lava flows do after 40 years.

This is also a good spot to reinforce that winds during cinder cone formation can cause the cone to take on an asymmetrical or lopsided shape.



Limber pine, the most common tree found in the monument, is a five-needle pine.

► Have the students look at both Silent Cone and Big Craters as examples.



The limber pine (*Pinus flexilis*) is the most common tree found in the Monument. It is very appropriately named, for you can take a small branch and literally tie it in a knot. Limber pine is a subalpine species (normally found growing just below timberline); however, it finds similar harsh living conditions here because of the strong winds present during the summer, just like the strong winds found near timberline. Being flexible is very important because it allows the tree to bend rather than break or get uprooted by the wind. Its needles have fewer stoma (openings used for respiration) than most pines, which helps it to conserve water, which is very important here in the high desert.

▶ *Limber pine represents a relic population that got started here on older cones about the close of the last ice age.*

▶ *Limber pine is usually found above 8,000 feet in Idaho, about a half mile higher than here.*



another 285 feet to the large limber pines at the curve on the trail ahead and continue the discussion there.

MISTLETOE

The Clark's Nutcracker is a pigeon-sized bird with a crow-like flight.



It takes 2 years for a limber pine cone to come to maturity, but when it does, it contains large pine nuts that feed many animals here at Craters of the Moon. The seeds are quite obviously too large to be dispersed by the wind, so the tree is dependent upon animals to distribute its seeds. The large gray jay-like bird commonly seen in the park around the limber pines is the Clark's nutcracker. A single Clark's nutcracker may make as many as 30,000 caches of limber pine nuts in a year, but never eats them all and therefore ends up planting new trees. Our pine squirrels also end up planting trees by caching nuts.

▶ *Clark's Nutcrackers have a sublingual pouch in which they can carry up to 17 pine nuts, but they usually only make caches of 5-7 nuts so that other animals can't steal all their food (i.e., don't put all your eggs in one basket).*

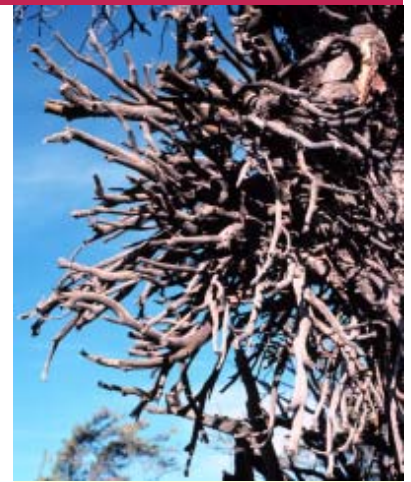
▶ *Have a couple of the students pick up one of the cones and find the scars left by the seeds; have them pass it around so that all the students can get an idea of how big the seeds are. If you are lucky and if you look carefully, you may even find a seed on the ground.*

The tree on the left side of the trail is a good place to see dwarf mistletoe. Look for yellowish shoots emerging from limbs. In late August, the berries, which look like fluid-filled blisters, swell and burst. The sticky seeds are ejected and carried on the wind to adjacent trees where they adhere to the needles. The mistletoe is a parasitic plant getting both sugars and water from its host tree. The mistletoe injects a hormone into the tree, which tells the tree to send more nutrients, which in turn causes the branch to swell and eventually causes a very dense branching pattern called witches' broom. Dwarf mistletoe rarely kills its host. There is no advantage for a parasite to kill its host because it would end up dying itself.



Dwarf mistletoe on a limber pine branch.

Desert parsley is an edible plant that was used as a salad green by the Indians. It looks like the parsley used as a garnish in restaurants. It is best if eaten before it has gone to seed, because afterward it is very bitter.



Witch's broom.

► **As you leave this stop, look around. There is usually some desert parsley in this area.**



► **PROCEED ...**

350 feet to the area just before the trail turns to the right and enters the open limber pine forest.

LOESS

The wind-blown soil that provides the growth medium for the plants here at Craters of the Moon is well exposed in this area. It is the tan-colored material exposed in the bank on the right side of the trail and has formed the tan mounds around many of the shrubs in this area. The scientific name for this material is **loess**. It is dominantly of silt size (silt is the particle size that falls in between very fine sand and clay-sized particles). The loess is material that was ground up by the glaciers up in the mountains, carried down onto the plains by the rivers that drain them, and subsequently sorted and transported by the wind. The dust that the students have been stirring up as they walked up the trail, unless it has rained recently, is loess.

It was mentioned earlier that the general pattern observed here at Craters of the Moon is that the older the flow or the cone, the more vegetation it has on it. Broken Top is an exception, one of those examples mother nature throws in to keep us humble, and what makes science more interesting. If you look across at Silent Cone you see a sagebrush steppe community on the south-facing slopes and an open limber pine forest on the north-facing slope. This is typical of a cone that is about 6,000 years old (Silent Cone is 6.5 Ka). Broken Top has this same pattern. You have sagebrush in front of you and as you proceed just a little further you will enter an open limber pine forest. Yet Broken Top is one of the youngest cones in the park. For some reason, a lot of loess has been deposited here in a short period of time. Perhaps Big Cinder and the unnamed cone behind the parking lot interrupted the wind sufficiently to cause a higher rate of deposition? A fire may also have remobilized soil that ended up deposited here.

- ▶ Have the students take a pinch of the soil, getting the cinders out first, and rub it between their fingers. The tan, powdery-feeling material left on their fingers is the loess. Geologists use this technique as a crude tool to tell particle sizes apart. Sand feels gritty, loess or silt feels like talcum powder, and clay rolls up into little cigars.
- ▶ Use this as an example of how easy it is to transport silt-sized particles.
- ▶ Ask the students if they noticed that the sagebrush was much more common once they moved onto the lee slopes. As wind speed slowed, particles carried on the wind were deposited in these areas.



View of asymmetrical shape of cinder cones from Big Sink Stop.

stop 2b

Sagebrush requires a deeper soil profile to survive than does rubber rabbitbrush or antelope bitterbrush. Note as you enter the forest that the trail has merged with an old road, which was once used to drive sheep to the Little Prairie to graze.



► PROCEED ...

315 feet around the corner into the open limber pine forest and stop at the large stump surrounded by a pile of pine cone debris on the right-hand side of the trail.

stop 2c

MIDDEN

The pile is an old midden produced by the “chickaree” or “pine squirrel”, which is a red squirrel. It is the smallest and most common squirrel throughout the Rocky Mountains. It is rust-red to grayish red above and white or grayish white below. This boisterous squirrel is often heard scolding hikers for being in its territory. The chickarees harvest large numbers of pine cones, which they store in middens for later use. These middens serve as their food banks for the winter; since they do not hibernate they remain active all winter. Chickarees are in competition with the Clark’s nutcrackers for the pine nuts and will harvest the cones and put them in their middens before the cones have opened up, giving the birds easy access.



STUDY OPTION: LUPINE AND RYE

Between the midden and the bank of cinders is a good place to point out lupine and giant or Great Basin wild rye. The lupine has lavender pea-like flowers and distinctive palmately compound leaves, each with 7-9 leaflets that radiate out from the tip of the leaf stalk. Lupine is a legume and fixes nitrogen, which adds to the fertility of the soil. The rye is easily distinguished by its height, between 3 and 4 feet. It was used by Native Americans as a grain and is an important food source for wildlife, especially in winter when other food is under snow.



Lupine.



Wild rye.



► PROCEED ...

650 feet to new spur trail.

BIG SINK SPUR TRAIL

A left turn at this junction will take you to the overlook of Big Sink.

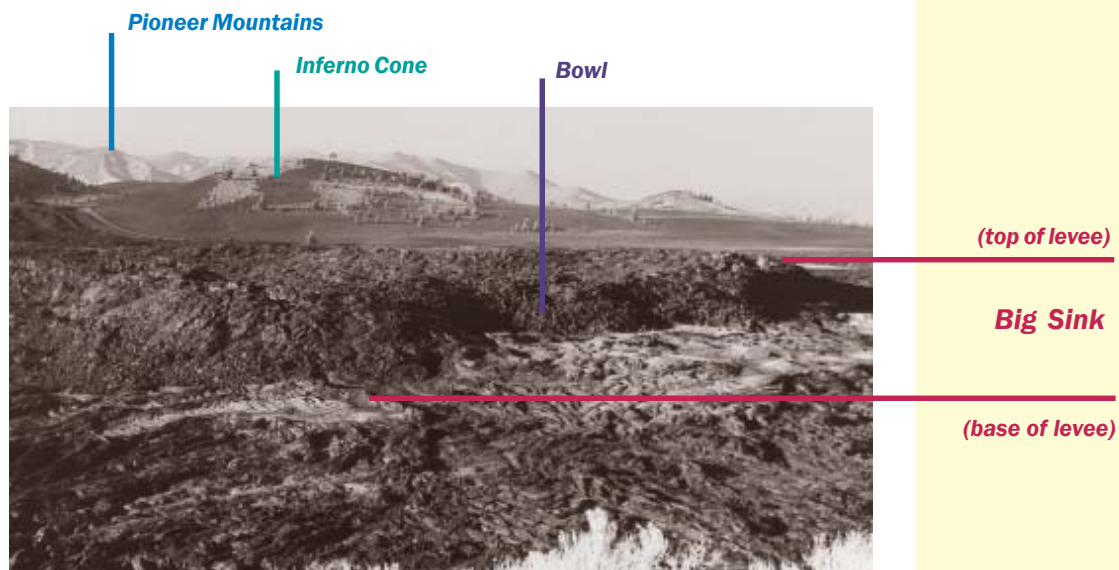


PROCEED ...

570 feet to the overlook platform.

BIG SINK OVERLOOK

The large bathtub-like structure (3 football fields long and over 50 feet deep) located across the street from here is named Big Sink, and it does look like a basin or washbowl for a giant. Perhaps it started as a tumulus or mound above the tube that ruptured open to form the pond. Lava levels within this pond probably moved up and down and occasionally found weak spots in the levees or dikes that formed from chilled lava at the edges. At various times, the lava broke out forming rivers or streams of lava, and even cascades. Finally, the lava drained back into the tube system and the still plastic crust on top of the pond draped down making a bowl shape.



Big Sink is the raised area in the center of the photo. Behind it is Inferno Cone, and in the far background are the Pioneer Mountains.

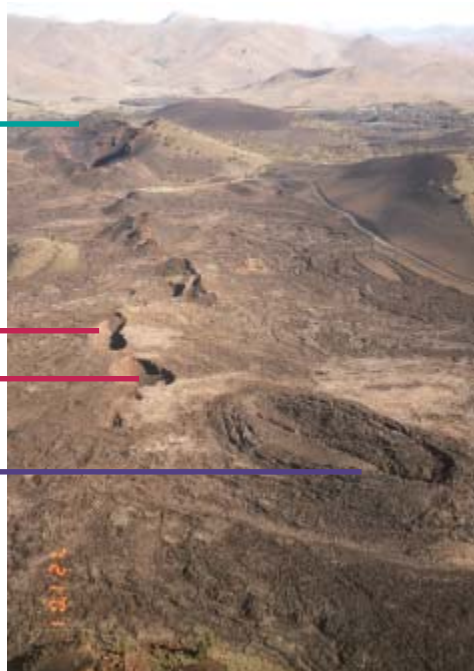
Big Sink as it appears from a low-flying aircraft.



Big Craters

Pit Craters

Little Sink

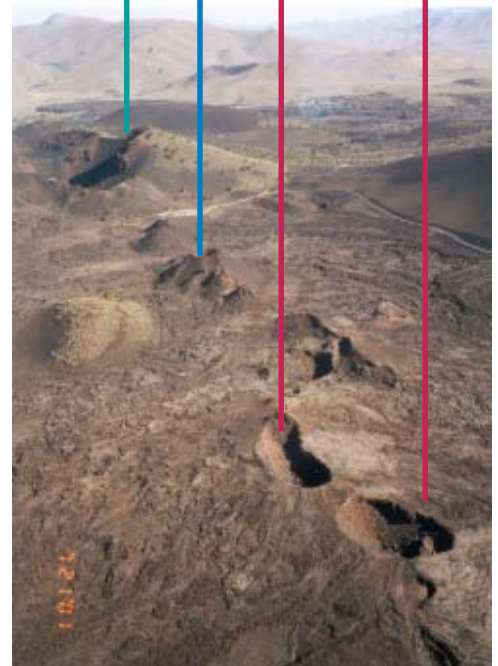


Views of features above Big Sink. These aerial photographs, along with the one of Big Sink on page 13, give an idea of some of the plumbing and features that will be talked about in the new waysides. Big Craters, top left, followed by the spatter cones, pit craters (collapses) and Little Sink.

Big Craters

Spatter Cones

Pit Craters



► **PROCEED ...**

570 feet back to the main trail and turn left, then go another 125 feet to the next stop along a large bank of cinders.

CINDER

You are on the far side of this cinder cone from the eruptive fissure out of which this material was ejected or thrown. Material thrown from a volcano is also known as ejecta or **pyroclastic** material. If the wind is blowing, lighter material is carried further downwind than heavier material. Many students will be amazed at just how light some of these cinders are. These cinders were highly gas charged and can be thought of as a froth, not unlike frothy slag which floats to the top in a blast furnace. These cinders can be thought of as volcanic slag from mother nature's blast furnace. Some of the cinders are light enough to float on water, but because the pores are usually fairly well interconnected they eventually fill with water, causing the cinders to sink. Pumice, on the other hand, which is frozen volcanic froth of a granitic rather than basaltic composition, usually has poorly interconnected pores and therefore can float almost indefinitely. In addition to being very light, many of the cinders in this bank exhibit a play of colors or an iridescence. The play of colors is believed to be caused by a very thin layer of glass on the surface of the cinder material, which refracts light much like an oil film on water.

Not all material thrown from a volcano is light in weight. Between here and the next stop keep an eye out for fragments of breadcrust bombs to show the students. Even though these bombs contain a lot of gas holes they are considerably denser than cinders. Breadcrust bombs form when globs of molten rock are thrown out and cool as they fly through the air. After a crust has formed on the glob, the gasses inside the bomb continue to expand, enlarging the bomb as it flies through the air and cracking the previously formed crust. This is very similar to what happens to bread that continues to rise in the oven as it bakes. Continued rising produces the cracked pattern in the crust. These bombs were named breadcrust bombs by volcanologists.



Iridescent cinder.

► Have students examine some of the cinders to see how light they are and look for cinders with a play of colors on them.

► **MAKE SURE THAT THE STUDENTS TOSS THE SPECIMENS THAT THEY HAVE BEEN LOOKING AT BACK ONTO THE BANK.** This might be a good time to remind them of how many visitors we get (~225,000) and what would happen if people were allowed to collect and take home souvenirs. Or bring it closer to home by asking students to imagine what this cinder bank would look like if each of the more than 4,000 school students that come here each year were to take a specimen. How many colorful cinders would be left? Would the bank change shape?

► **PROCEED ...**

590 feet to where the trail turns and goes down the hill.

VISTA

Look behind the shrubs on the left side of the trail. You should find a spindle bomb with a crescent shape hidden behind one of them. Spindle bombs are globs of molten rock that were ejected just like breadcrust bombs, but got twisted during their flight. Some take on a spiral or football shape, some end up looking like a star or sunburst, some look like giant twisted ribbons or other bizarre shapes, and some take on a crescent shape like the one you are looking at.

From the time you left the open limber pine forest you have been walking across a different terrain, an area of hummocks and hollows. What caused this to happen to the cone? This is not the way cinder cones normally look. Also, look off to the north and notice that there are lava beds that are tilted up sharply. Examination of these lava beds shows that they were laid down flat and were tilted up later. There are two hypotheses that explain both the hummocky topography and the tilted lava beds. The first hypothesis is that collapse back into the magma chamber after it emptied produced these features. It is easy to picture producing the hummocks and hollows from collapse, but not so easy to picture it causing the lava beds to be tilted. An analogy that might help the students is that the collapse is similar to pushing down on a balloon with your hand; it causes a raised edge to form around your hand. The second hypothesis is that some reinflation of the cone occurred associated with the Broken Top flows. The reinflation was not uniform and this chopped up part of the cone, producing the hummocky terrain and also tilting up the lava beds around the edge of part of the cone. An analogy of this might be inflating a rubber glove and where the fingers poked up you got hummocks.



Crescent-shaped spindle bomb.

SAFETY MESSAGE

Be careful when you pick the spindle bomb up, it is heavy.

Please put the bomb back out of sight after you have shown it to the students to reduce the chance of vandalism.



Tilted lava beds that were originally laid down flat.

The large mountain rising from the floor of the plain about 25 miles to the east of here is Big Southern Butte. It is a different kind of volcano than those we have here at Craters of the Moon. It is a rhyolite dome that formed as rhyolitic magma slowly rose up through the layers of older basalt. The magma pushed the overlying layers upward, broke through, and flowed slowly onto the surface; Big Southern Butte is 300 Ka in age. East Butte, which is closer to Idaho Falls and has an assortment of radio and TV broadcast antennas on it, is 600 Ka in age. Some layers of basalt on Big Southern Butte were broken and carried up as the dome grew. These can be seen as you drive along HWY 20 to Idaho Falls. All that you can see on Middle Butte, which lies between Big Southern and East Buttes is domed-up basalt; it is believed to be the same age as East Butte.

Another kind of volcano is visible from this vista as well. Just this side of Big Southern Butte where the sky and land meet you can see several small shield volcanoes. They are convex up, gently arched structures that reminded early geologists of a knight's shield laying on the ground, hence the name shield volcano. Shield volcanoes are mostly made up only of lava flows; usually very little ash or cinders is erupted from the vent that produces them. As the lava continues to pour from the vent over a long period of time, the gently sloped mounds you see near the horizon are formed. As shield volcanoes go, these are small ones, particularly in comparison with the Hawaiian Islands, which are huge shield volcanoes.

► *The parent material for the rhyolite was basalt. It was separated off much like grease floating to the top of a pot of stew. The process is called fractionation or extreme differentiation.*



Big Southern Butte.

► *The Eastern Snake River Plain is believed to be made up of about 8,000 shield volcanoes.*



Look over at Big Cinder and you can see discrete layers of rock. These layers are not lava flows, but rather agglutinated cinders. Sometimes the cinders are so hot when they land that they weld or sinter themselves together in a process that geologists call agglutination. Notice that some of these layers have failed in landslide, not unlike a slab release avalanche. Based on the vegetation growing below these failures, they must have occurred long ago.

The densely (relatively speaking) vegetated lava flow before you is the Broken Top Flow and it is the youngest one in the park (~2 Ka). This is another of the exceptions to the general pattern of older volcanic features having more vegetation than younger ones. A geologic explanation will be given later in this guide when we talk about the Broken Top Flow again.



Watch for deer tracks along the way.



► Ask the students to come up with an explanation.



► PROCEED ...

580 feet down the trail and stop at the tall boulders covered with lichens on the right side of the trail.